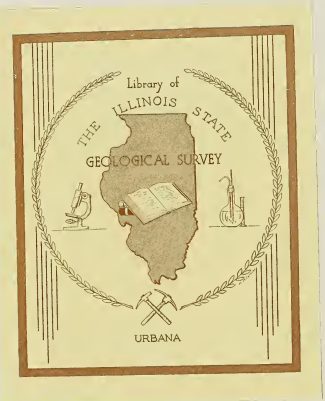

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STATE OF ILLINOIS
WILLIAM G. STRATTON, *Governor*
DEPARTMENT OF REGISTRATION AND EDUCATION
VERA M. BINKS, *Director*

DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*
URBANA

CIRCULAR NO. 186

MINERAL RESOURCE RESEARCH AND ACTIVITIES OF THE STATE GEOLOGICAL SURVEY, 1952-1953

BY

M. M. LEIGHTON, *Chief*

Reprinted from the Annual Report of the Chief to the Director,
Department of Registration and Education,
for Fiscal Year 1952-1953

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Figure 1.—The Natural Resources Building, on the University of Illinois campus, was constructed to house the offices and laboratories of the Geological Survey and the Natural History Survey divisions of the Department of Registration and Education. The central unit was built in 1940; wings added to the east and west were occupied in 1950.

Dr. M. M. Leighton

MINERAL RESOURCE RESEARCH AND ACTIVITIES

of the

STATE GEOLOGICAL SURVEY

1952-1953

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M. M. Leighton, Chief

The present is rooted in the past. Few, perhaps, realize how dramatically this fundamental truth applies to the material well-being and industrial stability of present-day Illinois, and how extremely remote is the "past" on which our modern society rests. The stage was set many millions of years ago. No one can say accurately when the curtain rose, but the cast of characters included land and sea, wind and rain, heat and cold, running water, underground water, climate, earth movements, and countless living organisms, both plant and animal. All played their parts well under the incomparable direction of natural laws and time.

As the drama unfolded in Illinois, vast beds of coal were formed; extensive layers of valuable limestone, dolomite, clay and shale, and sandstone were laid down; deposits of fluorspar, zinc, and lead filled cracks and crevices in many places; and oil and gas formed and accumulated in porous rocks. A very important bit of natural scene-shifting was accomplished late in the play and a major role was filled by the great ice sheets which advanced from the north and covered most of

the State, leaving in their wake, as they retreated northward from the stage, a blanket of unconsolidated material which provided the setting for the development of rich soils; buried stream valleys containing sand and gravel, later to hold abundant resources of groundwater; new watersheds and stream patterns; some new stream valleys destined to become lines of travel and transport; and even the Great Lakes whose broad navigable waters were to put Illinois into ready communication with Canada, the Atlantic, and the Gulf.

The last act in this drama of the past opened with the appearance of the hero of the play—man. Without the dynamic character of the white man, all the millions of years that preceded his entrance upon the stage would have accomplished just so much stage setting. It is man who has discovered and developed and turned to usefulness the vast resources built up through millenia by Nature.

Some indication of the value of this great natural treasure may be gathered from the following table showing value of minerals produced in Illinois in 1952:

Coal	$186,671,000
Oil and gas	175,663,000
Clay and clay products	43,317,000
Limestone and dolomite	18,167,000
Cement	21,587,000
Fluorspar	9,522,000
Special sand	7,557,000
Sand and gravel	9,598,000
Zinc, lead and silver	7,909,000
Lime	3,750,000
Ground silica	2,436,000
	$486,177,000

In addition, the value of minerals processed in Illinois, though for the most part mined elsewhere, amounted to $388,484,000. These include pig iron, coke and by-products, slab zinc, and others. Of significance also is the fact that minerals and mineral products accounted for 52.8 per cent of the revenue freight originating in Illinois in 1952. Thus the combined value of minerals produced and processed in Illinois in 1952 totaled approximately 875 million dollars. No other state in the Upper Mississippi Valley has such a mineral heritage.

Organization and Duties

Illinois has been fortunate in having had at the helm of its government men who have been aware of the values that ensue from the development of its natural resources. As early as 1851, geological in-

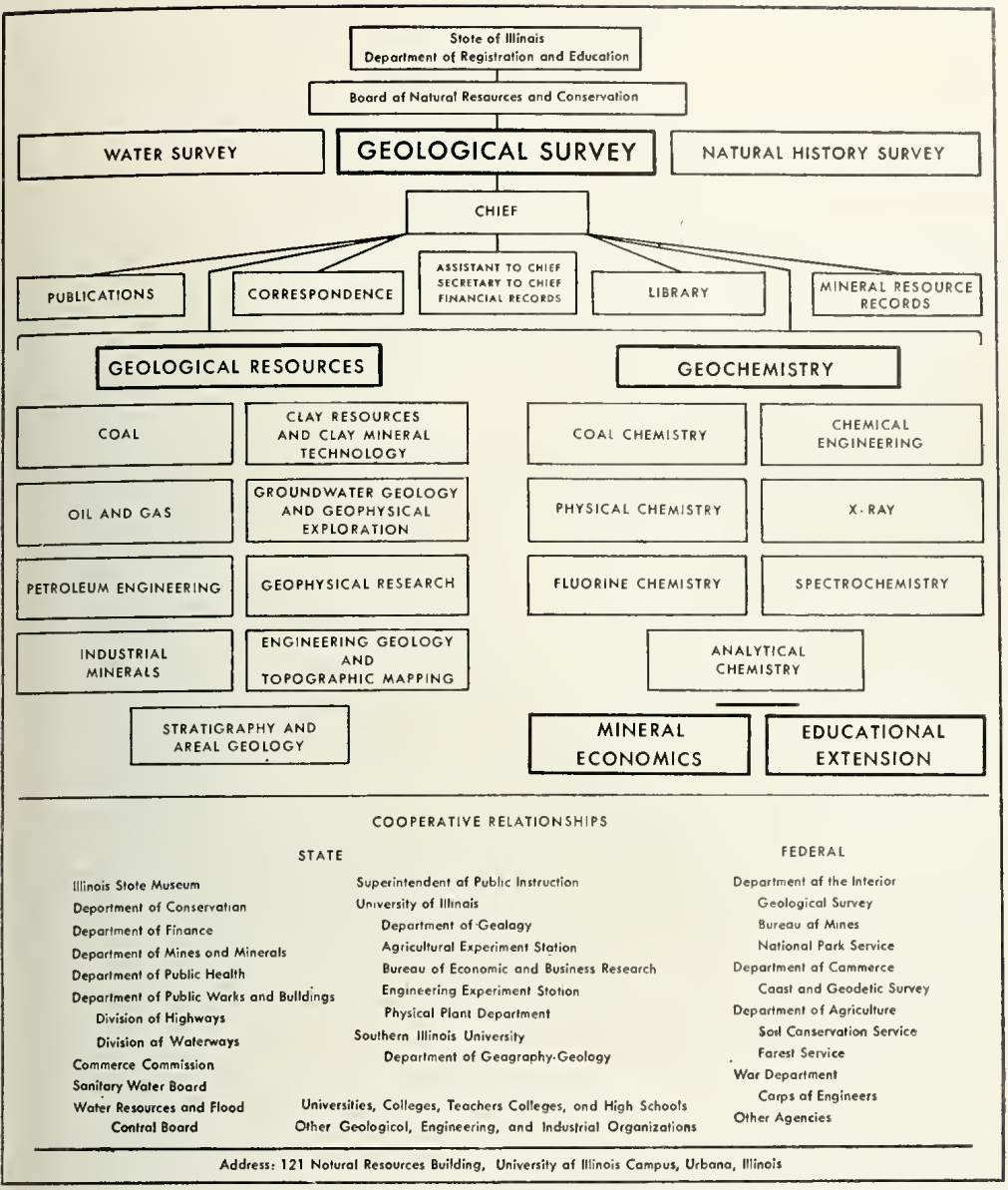


Figure 2.

Organization chart.

vestigations were sponsored by State government, but industry and technology were at low ebb, and the studies, based on the science of that day, were permitted to lapse. In 1905 the State Geological Survey was re-established to meet the needs of rapidly growing industry.

The Survey is the agency of the State charged with the responsibility of studying and reporting upon the geological conditions and mineral resources of Illinois. Research and investigation of a high scientific order is carried on both in the field and in the laboratory, and close relationships are maintained with industry in order to keep

in touch with its needs and with modern technological developments. Through letters and personal conferences and through its many publications, the Survey seeks to provide accurate information on the State's known and potential mineral resources to landowners, producers, manufacturers, consumers, and interested citizens.

The internal organization of the Survey, shown diagrammatically in Figure 2, is designed to coordinate research in varied but closely related fields so that results may be well rounded and comprehensive. In 1952 its scientific and technical staff included 49 geologists, 21 chemists, 6 engineers, a mineral economist, 2 physicists, a supporting staff of editors, a librarian, a photographer, and more than 35 specially trained research and technical assistants.

The Survey's offices and research laboratories are housed in the Natural Resources Building (Figure 1), which was designed especially for the work and was erected on the University of Illinois campus in Urbana in 1940 and enlarged in 1950. They include, in addition to administrative and research offices, some 40 laboratories equipped with the most modern scientific apparatus for geological, chemical, and physical research, including X-ray and spectrography. A separate building (Figure 3) provides facilities for larger-scale experimental work than can be done in the Survey's laboratories.

Financial Statement

The amount appropriated to the State Geological Survey for the biennium beginning July 1, 1951 and ending June 30, 1953 was as follows:

Personal Services:	
Regular Positions	$1,297,200
Extra Help	36,190
Contractual Services	34,200
Office Expenses:	
Postage	6,500
Other	3,300
Travel	37,000
Commodities	71,300
Stationery, Printing, and Office Supplies	62,000
Equipment	19,700
Topographic Surveys	62,500
Employer Contributions to University Retirement System	28,830
	$1,658,720

The amount available for the second year of the biennium, July 1, 1952 to June 30, 1953, was $914,433.

The actual expenditures and estimated expenditures on contracts through the year ending June 30, 1953 were distributed among the following activities:

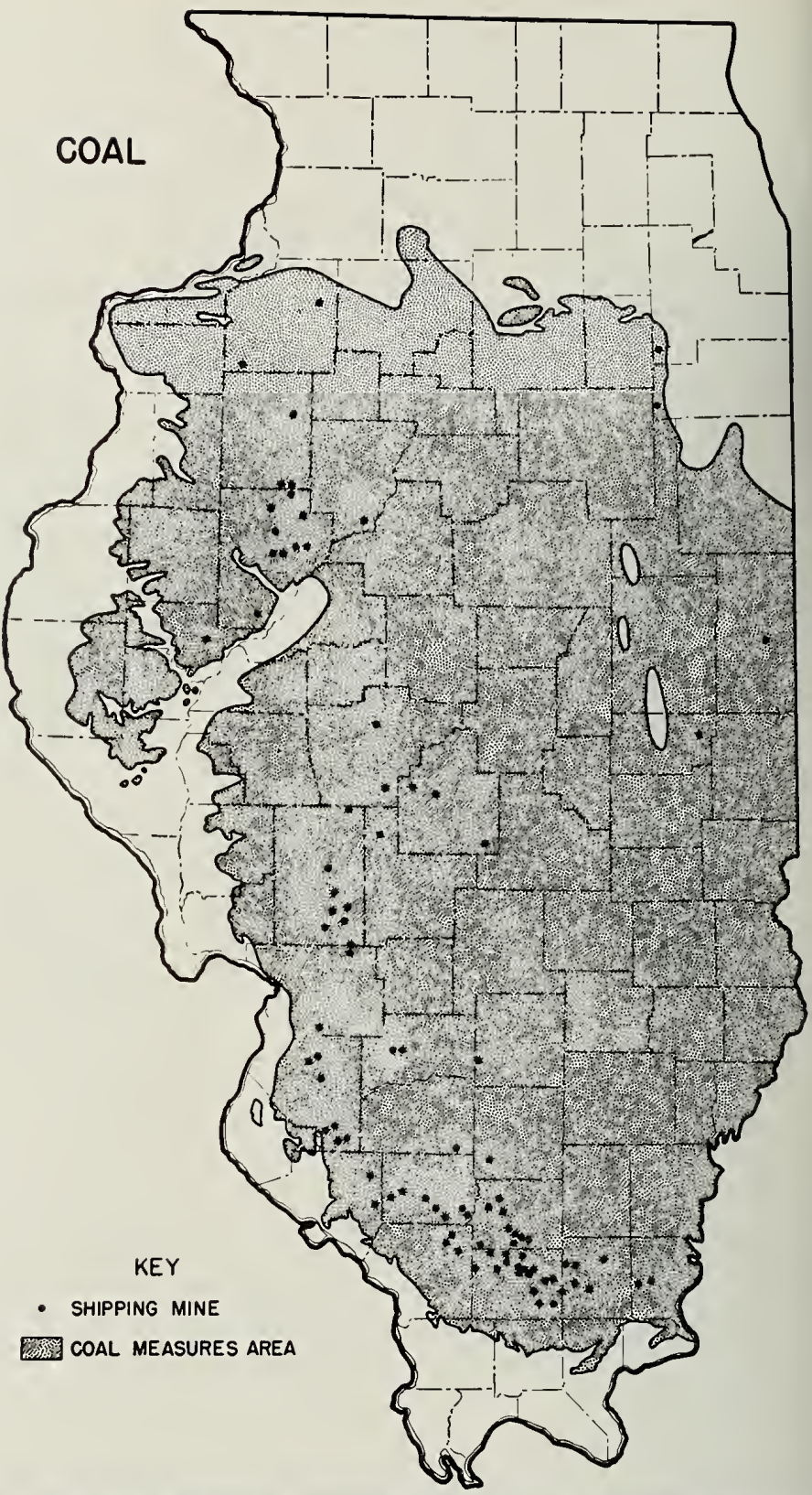
Coal (Geology and Chemistry)	$146,750
Oil and Gas and Petroleum Engineering	57,151
Industrial Minerals (Geology and Chemistry)	66,203
Clay Resources and Clay Mineral Technology	18,967
Fluorine Chemistry	16,448
Groundwater Geology and Geophysical Exploration	57,131
Engineering Geology	11,884
Stratigraphy and Areal Geology	77,393
Analytical Chemistry	61,637
X-ray	8,598
Mineral Economics	17,260
Topographic Mapping	39,206
Educational Extension	14,196
Mineral Resource Records	21,811
Library	13,862
Publications (including printing)	58,120
Other Technical Services, including Photography and Equipment Design	21,997
Clerical Services	23,251
Automotive Services	14,360
General Administration, including Chief's Office, Financial Records, Technical Records, General Information Office, Technical Supplies, Postage, and some Contractual Services	89,440
University Retirement System of Illinois	14,415
	$850,080

RESEARCH ACTIVITIES

Coal

Coal is Illinois' most valuable single mineral resource. In 1952, 45,753,000 tons valued at $186,671,000 were produced in Illinois. Illinois ranked fourth among the states in production of coal, its output accounting for about 10 per cent of the national total.

New mines were opened during the year in Randolph, Christian, Williamson, and Gallatin counties, and the production from these mines will serve to offset the loss in production resulting from the enforced abandonment of numerous other operations which had reached their economic limit. The recent establishment and expansion of



More than half of Illinois is underlain by the Coal Measures. Dots show locations of shipping mines as of January 1, 1953.

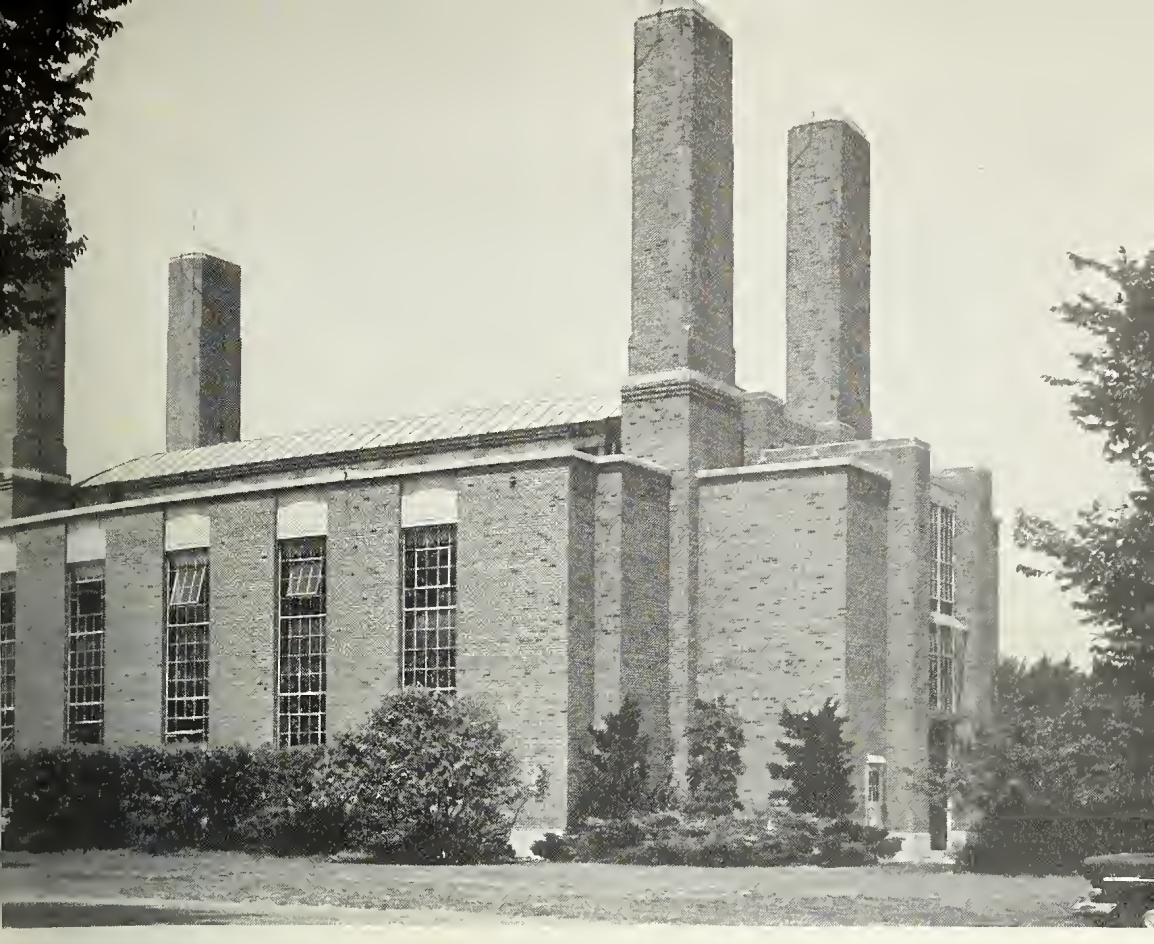


Figure 3.

The Geological Survey's Applied Research Laboratory where semi-plant-scale experiments work toward improved products from Illinois coal resources.

power plant facilities along the Ohio and Tennessee rivers is opening a tremendous new market for Illinois coal. It is estimated that these plants will ultimately require some 17 million tons of coal per year, half of which will probably come from Illinois mines.

1. *New deposits of workable coal,* capable of meeting strong competition, must be found if the industry is to sustain itself and continue its important contribution to the nation's output of this vital resource. The industry continues vigorous exploration for such new deposits, and the Geological Survey lends invaluable assistance to the search by making available its rich file of drilling records throughout the State, evaluating areas for prospecting, interpreting diamond drill tests made by the operators, and furnishing information on the rank and quality of the coal, county by county. In no other single place is there so complete an assemblage of data as in the Survey files. Survey geologists are continually engaged in research to determine the position, extent, character, availability, and quantity of our coal resources. The past year has seen the virtual completion of a study of "coal measures" strata in an area including parts of Effingham, Fayette, Montgomery,

Bond, and Madison counties and the compilation of basic data from approximately 1,700 well records for a similar report on Wayne County. From the interpretation of electric logs, a number of informative cross sections of Pennsylvanian ("coal measures") strata have been prepared and a study of the complicated Cottage Grove fault area in Gallatin County is in progress. Structure maps of the No. 5 and No. 6 coals in Gallatin County have been completed, and a map showing pre-Pennsylvanian geology and the thickness of lower Pennsylvanian rocks in the area is in an advanced stage of preparation. During the year, also, 25,000 feet of diamond drill cores from Christian, St. Clair, Saline, Williamson, and Gallatin counties have been studied and described. Studies such as these not only help the search for coal, but are equally valuable in the search for underground geological structures favorable to the accumulation of oil and gas.

2. *New maps showing the coal resources of the State* are in press and will be available for distribution in the summer of 1953. Preparation of these maps was undertaken at the request of the National Bituminous Coal Advisory Council of the Federal Government in accordance with their adopted plan as recommended by the Chief of the Illinois Geological Survey for inventorying the nation's coal reserves. The maps will accompany a comprehensive report on the minable coal reserves of Illinois which will show coal resources in four classes: Class 1A, proved; Class 1B, probable; Class 2A, strongly indicated; and Class 2B, weakly indicated. It will also show coal classified in terms of thickness at steps of 28, 42, 54, 66, 78, 90, 102, 114, 126, and 132 inches of thickness. This report with accompanying maps, which has been some two years in preparation, will bring together for the first time, and in clearly tabulated form, a vast amount of statistical information and will be an exceedingly valuable contribution to general knowledge of the State's coal resources as of 1950.

3. *Maps of mined-out areas* on a scale of 1 inch to the mile were prepared in connection with the above-mentioned inventory of coal resources. These are being transferred to tracing linen so that copies may be made to meet the requests of the coal and oil industries and the public, for the cost of blueprinting.

4. *The geology of mine roofs* has been the object of special study by the Survey to determine the geologic conditions influencing the strength or weakness of coal mine roof materials, especially shale. Approximately 50 per cent of all coal mine fatalities are due to falls of roof rock and coal. Greater safety and better coal mine practice will result from improved roof control. During the past year some 70 coal mines working in the No. 6 seam in every mining district in the central and southern part of the State were studied. Roof conditions were observed as well as roof bolting procedures and the behavior of bolted

roofs under various compositions of rock strata and structures. The data collected have been assembled on maps on a scale of one inch to the mile. About 400 samples of roof rock were taken and, together with some diamond drill cores, are being prepared for laboratory testing.

5. A *new market for Illinois coal* has resulted directly from the Survey's research on the use of Illinois coal in the manufacture of metallurgical coke. Prior to 1943, when this investigation was first undertaken as a War Production Board project to reduce railroad hauling of coking coals from Eastern fields, there was general doubt that Illinois coal was suitable for the manufacture of metallurgical coke. A pilot plant oven of 500-pound capacity, designed and constructed by members of the Survey staff, was put into operation in the Survey's Applied Research Laboratory. With the cooperation of coal operators and steel companies, it was successfully demonstrated that Illinois coals could be used in blends with Eastern coals to produce metallurgical coke of standard quality. Within four months of the first runs in the Survey's laboratory, Illinois coal was used in commercial ovens at Granite City, where it has been used continuously since then. During

Discharging coke from experimental slot-type oven which was recently designed and built by engineers and chemists of the State Geological Survey to determine pressures that must be withstood by the side walls of ovens using Illinois coals in blends for the production of metallurgical coke.

the last year of the war, use of Illinois coal in this one plant alone saved transportation amounting to 2,326,700 car-miles (not including return of empty cars), or the equivalent of a train of 100 cars operating continuously throughout the year. Approximately 4,000,000 tons of Illinois coal has been consumed in the production of metallurgical coke in the past nine years. Average annual consumption for the last five years is in excess of 500,000 tons. It is estimated that this gave employment to 433 coal miners for each of the five years.

During the past year, special attention has been given to the expansion-pressure properties of coal blends and the determination of the effect of Illinois coals on expansion as compared with that of the Eastern coals for which it is substituted. There is critical need in the industry for specific data on this matter to prevent disruption of commercial ovens. A new movable-wall pilot oven, designed and constructed by members of the Survey staff in recent months, has been under heat and in operation since May and will make possible the accurate measurement of expansion pressures.

Experimental work is being continued in close cooperation with industry. Inquiries regarding Illinois coals for coking have been received from several sources, including a $66,000,000 steel plant under consideration at Clinton, Iowa, where a projected battery of 96 coke ovens would consume approximately 790,000 tons of coal per year. The new battery of 27 coke ovens being built at Granite City, where Illinois coal is already in use, will increase the consumption of Illinois coal by an estimated 144,000 tons per year. Fifteen new ovens have been completed during the year by a large steel company in the Chicago area, where 20 per cent Illinois coal is used, and this likewise has increased the Illinois tonnage. Another recent inquiry, now under investigation, involves the possible use of Illinois coal to replace West Virginia coal in the reduction of zinc ore at an Illinois plant. It is through well-conceived and carefully directed research that practical results of great value to operators, miners, industry, and the general public are achieved.

6. *Preparation of low-volatile char from Illinois coals* and its use in metallurgical coke blends as a substitute for Pocahontas coal, now generally used in the coking plants of Illinois steel companies, constitutes another line of research which has been carried on hand-in-hand with the Survey's coking studies. In order to produce chars over a range of operating conditions and to control the volatile matter at any practical point, a pilot plant for continuous production of char was designed and built in 1948-49. Nearly two hundred chars have been made, mostly from Illinois coals, the chars ranging from 15 per cent to 24 per cent in volatile matter. Results to date indicate that the quality of coke produced from coal-char blends depends primarily upon the high-volatile coals with which the char is blended, and that with proper selection of the high-volatile coals, Illinois char can be used to produce coke with good metallurgical properties. This work, therefore, shows promise.

7. *Research on stoker coal* with a view to improving stoker fuel has been in progress in the Survey's Applied Research Laboratory for some time. Results demonstrating the relationships between the combustion characteristics of coal and its chemical and physical composition, as well as the effect of coal size on combustion characteristics, have been published. Special studies carried on during the past year have included such matters as the effect upon combustion of adding a freeze-proofing agent, methods of improving the combustion characteristics of certain specific coals, the effect of six-months' storage on the combustion properties of Illinois coals, and comparative combustion tests of stoker briquets made from fine coal and of commercial stoker coal from the same mine.

8. *The most modern research techniques* are being applied to various lines of investigation into the physical and chemical properties of coal in order to improve the state of knowledge of the real nature of this complex material. Chemical, thermal, and X-ray analyses; microscopic examination of the banded ingredients of coal; the preparation and study of polished sections; and physico-chemical determinations of the surface properties of fine coal are all being pursued in the Geological Survey's laboratories. Knowledge so gained must inevitably lead to better methods of coal preparation and utilization, and even to the development of currently unrecognized potential uses for coal and coal derivatives in the chemical industry. Two papers dealing with the chemistry of coal have been published during the past year, and a report on petrographic and microchemical studies of coal has been completed for publication.

9. *Highly specialized studies of the botanical constituents of coal* have brought the Illinois Geological Survey national renown in this field. Separation, identification, and study of the plant particles in coal is done by a professionally trained paleobotanist, and the material so isolated is also analyzed microchemically. This work has proved useful in the identification and correlation of coal beds and is throwing light on relationships of the character of plant material to the rank of the coals and their combustion characteristics. During the past year more than 200 "coal balls" (rounded accumulations of singularly well-preserved fossil plant material found in Illinois coal) have been catalogued, cut, ground, etched, and examined microscopically.

10. *Marked improvement in quality of coal purchased by the State* for its various institutions has resulted from the Geological Survey's sampling and analyzing of coals for this purpose. Twice each year, a member of the Geological Survey's staff makes the rounds of the 31 state institutions which use coal for boiler fuel, and keeps the engineering staffs of those institutions informed on sampling and preparation methods. During the year covered by this report, 455 samples were received, analyzed, and reported upon to the State Division of Purchases.

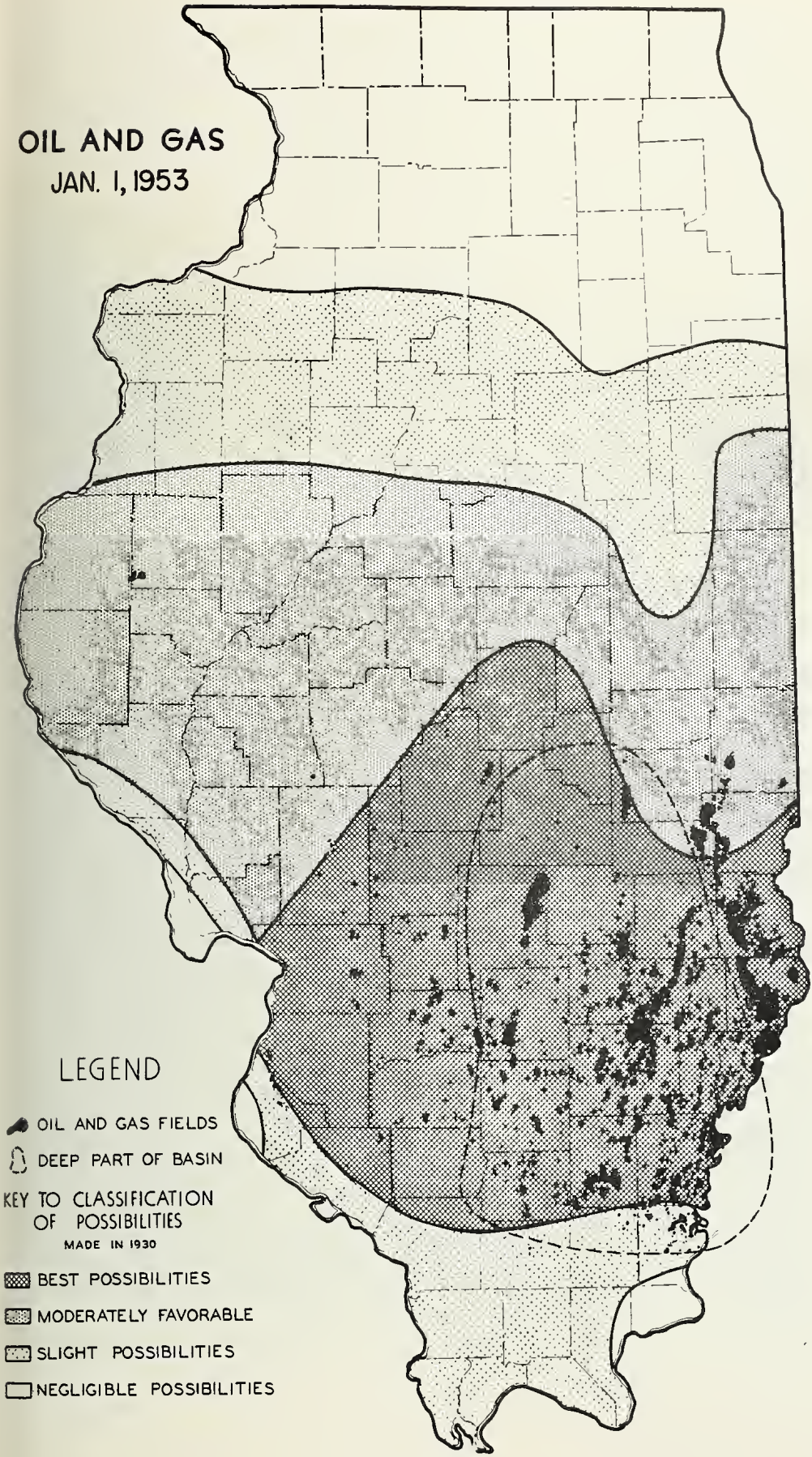
Oil and Gas

During 1952, Illinois produced a total of more than 60,000,000 barrels of oil valued at more than $166,000,000. Proved reserves in the known pools of the State were estimated at 639,707,000 barrels as of December 31, 1952. In the twelve months ending April 30, 1953, 19 new pools, 52 extensions to pools, and 27 new "pay sands" were discovered. In the past two or three years there has been considerable interest in testing for deep production and, in the new pools and "pays" just referred to, there are numerous discoveries of production from rock horizons below those which have furnished the larger part of the State's oil to date.

11. *Intensive search for new oil* is carried on unceasingly by the petroleum industry to meet market demands. Oil and gas and their products are needed in increasing amounts by transportation, industry, agriculture, and the public. The State Geological Survey renders continuous assistance to the search by making available the immense amount of information in its possession. Hundreds of thousands of well records and samples of drill cuttings and cores are in the Survey's files and they are constantly being increased. Members of its scientific staff study, interpret, and correlate the geology revealed by these records; prepare maps, cross sections, and reports; answer inquiries by letter, telephone, and personal conference; and help in every possible way to guide and inform operators, landowners, and interested citizens.

12. A *revised report and geologic structure map* of the southern two-thirds of the State, based on the New Albany shale, is in preparation. It will replace a similar report published by the Survey in 1943, since which time many new wells have been drilled and much more information obtained. The new report will include two cross sections: one to extend from Calhoun County on the Mississippi River beyond the Illinois-Indiana boundary; the other to extend southward from Madison County almost to the southern border of Jackson County. It will also include an index map of the Eastern Interior basin, the Illinois basin, and principal structural axes and faults, as well as an isopach map of the interval from the top of the Menard formation in the upper part of the Chester series to the base of the New Albany shale.

13. *Geologic studies of selected areas* or formations are in progress. A study of the geologic structural history of the Centralia area in parts of Clinton, Jefferson, Marion, and Washington counties has been completed, and a report is being prepared for publication. Geological information which is assembled from time to time in connection with replies to specific inquiries is posted on large-scale maps so that it is available in graphic form in future studies of the whole field.


OIL AND GAS
JAN. 1, 1953
LEGEND
OIL AND GAS FIELDS
DEEP PART OF BASIN
KEY TO CLASSIFICATION OF POSSIBILITIES
MADE IN 1930
BEST POSSIBILITIES
MODERATELY FAVORABLE
SLIGHT POSSIBILITIES
NEGLIGIBLE POSSIBILITIES

14. *Periodic reports.* Monthly reports on oil and gas drilling activities throughout the State are prepared and issued in mimeographed form. These reports are widely used by the petroleum industry, State and Government officials, landowners, businessmen, and others interested in current oil field activity, and more than 500 are distributed monthly on a subscription basis.

Special monthly reports are also prepared for the use of the Interstate Oil Compact Commission and for certain trade journals, news is furnished to the Illinois Oil and Gas Association for its monthly letter, and a monthly report is made to the Petroleum Administration for Defense on the amount of casing used by oil operators in the State.

Development maps on a scale of two inches to the mile, showing the location and current status of all wells drilled, have been prepared for 47 areas, each covering nine townships. Master copies on tracing linen are revised every three months and copies are available at the cost of blueprinting. Approximately 1,400 of these maps were distributed during the past year. Maps of two new areas, the Flatrock and Robinson, are in preparation, and with their completion the entire southeastern Illinois oil field area will be covered.

Diamond drill cores from deep rock formations being studied, at site of drilling, by a staff geologist of the State Geological Survey.

15. *Statistical analyses of oil and gas development in Illinois* are compiled each year, published by the American Institute of Mining and Metallurgical Engineers, and simultaneously reprinted by the Survey. Such reports have been published without interruption since 1933 and comprise a very valuable historical record of activities relating to oil and gas in Illinois during those 20 years. The Survey also cooperates each year with the American Petroleum Institute Committee on Reserves for Illinois by furnishing the latest available data on estimated reserves for the State.

16. *Free information service* of great value to landowners, professional geologists, and oil operators is rendered by the Survey's Oil and Gas Division. Securing only part of the basic data necessary to this service occupies the full time of two members of the Division. One acts as oil scout and in this capacity covers approximately the north half of the State and attends the weekly meeting of the Illinois Basin Scout Association, which is a clearing house for current drilling information. Another man is almost continually in the field collecting drill samples and cores from recently drilled wells and samples of oil, gas, and brine, and making measurements of gas flow in gas and oil wells for the purpose of calculating gas-oil ratios. The remainder of the necessary basic data is directly filed with the Survey by oil companies in the form of driller's logs, drilling time logs, electric logs, and sample cuttings and cores, in accordance with State requirements, and by the study of these data and preparation of logs by members of the Survey staff.

Information is given by letter, over the telephone, and in personal conferences. Approximately 1,200 requests for information were received and handled during the past year, more than 350 of them by personal conference or long distance telephone. The extent to which the public calls upon the Geological Survey is in itself a tribute to the service rendered, and the Survey receives many expressions of appreciation of the prompt, courteous, and informative response to public inquiries.

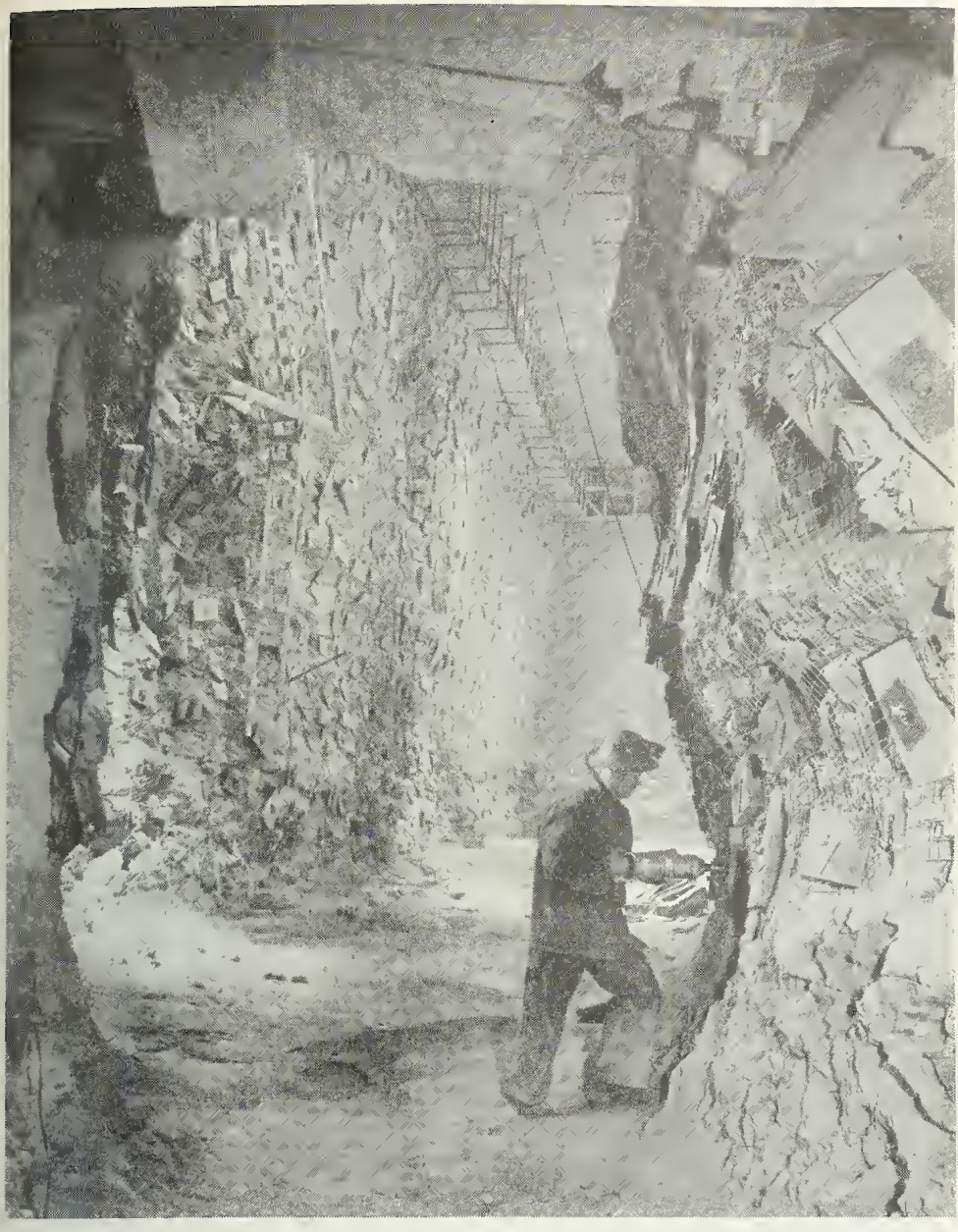
Petroleum Engineering

Second in importance only to the discovery of oil is the extraction from the natural rock reservoir of the maximum amount of oil economically possible. With the continuing high demand for petroleum and its products and the likelihood of eventually diminished reserves, the science of petroleum engineering is becoming an increasingly important factor in the development of the nation's oil resources. In order to secure more comprehensive engineering data and to be able to render effective assistance in this rapidly expanding field, the Geological Survey organized a separate division of Petroleum Engineering in 1951 and has been giving special study to many fundamental and applied principles of oil field engineering.

17. *Water flooding of oil "sands"* is a method for the secondary recovery of oil after pumpage has declined below the limit of economic production. The oil is "flushed" out of the reservoir by forcing water down input wells. This method was introduced in Illinois a number of years ago, largely as a result of the Geological Survey's recommendation. During 1952 the amount of oil produced in Illinois by this method is estimated at approximately 10,000,000 barrels, having an estimated value of $27,700,000, and accounting for nearly 17 per cent of the State's total production. The amount of oil so recovered each year has increased steadily since 1943, when 15,000 barrels were recovered, and the total oil produced by water flooding methods in the past ten years is estimated at 37,878,000 barrels. There can be no doubt, therefore, that the application of water flooding has been a critical factor in keeping the State's annual oil production at a high level.

The Geological Survey is studying the various physical and chemical factors which relate to the problem of water flooding. One such investigation deals with the physical properties of Illinois crude oil, its viscosity and specific gravity at varying temperatures, and the interfacial tension between crude oil and water. This study is basic to an understanding of the flow of fluids through oil reservoirs. Research is also in progress on the porosity and permeability of oil sands and, through the cooperation of a committee of the American Petroleum Institute,

A large, modern water-treating plant used in secondary oil recovery operations under a unitized plan for the Salem, Illinois, pool. (Photograph through the courtesy of The Texas Company.)



Underground cavern of Phillips Petroleum Co. for storage of liquid gases.

samples and cores of producing sands from oil fields in the State have been received. Still another very important factor being investigated is the clay mineral content of the various oil sands. Certain clay minerals swell when wet and by clogging the oil sands could seriously endanger the success of a water flooding operation after the venture is under way. It has also been discovered that certain sulphate-reducing bacteria found in oil field brines cause trouble in water flooding by producing a precipitate which impedes the flow of water through the sand. Conferences have been held by members of the Survey's staff with representatives

from one of the major oil companies and members of the State Natural History Survey staff to explore the possibilities of research to help solve this problem.

18. *Underground storage* of natural gas and liquefied petroleum gases is a comparatively new undertaking of industrial significance. By this process billions of cubic feet of gas or hundreds of thousands of barrels of liquefied petroleum gases can be stored in natural underground reservoirs or in mined-out caverns at much less cost than in tanks above ground. Winter gas shortages can thus be avoided, and great savings in steel can be realized. Geologic conditions underground, however, must meet very rigid specifications if any such undertaking is to prove feasible. A great deal of accurate geologic and engineering data are therefore necessary in prospecting for appropriate sites, and the Geological Survey has been called upon to furnish information on potential geologic structures in the State. During the past year one major storage project has been completed and several others are in various stages of development.

Clay and Clay Products

The value of clay and clay products produced in Illinois in 1952 amounted to an estimated 43 million dollars. Refractories accounted for some $10,880,000, and the values of other clay products were: common brick, $7,734,000; face brick, $4,783,000; other structural clay products (paving block, sewer pipe, drain and structural tile, terra cotta, etc.), $4,248,000; and pottery, $14,565,000.

19. *Fundamental research on clay* is one of the outstanding achievements of the Illinois State Geological Survey. More than twenty years ago the Survey inaugurated a comprehensive program of research on the physical, chemical, and atomic structure of the group of minerals called clay minerals. Prior to that time comparatively little was known concerning the internal mineralogic structure of clay—one of the least spectacular but most valuable of the State's mineral resources. Since that time information has been obtained which has revolutionized our knowledge of the many kinds of clays, their uses, and beneficiating practices, significant both to science and to the solution of practical industrial problems. Because of its work, the Survey has become known throughout the world, and visitors from many foreign countries have come to visit the Survey's laboratories and to observe its research techniques.

20. *Practical results of great value* to the clay industry have resulted. Industrial processing problems have been solved, products have been improved, and new products have been made. Prospecting methods for clay resources of a certain kind have been rationalized. The kinds and proportions of clay minerals in a deposit, the textural character,

Airplane view of Illinois Clay Products plant in northern Illinois.

the impurities, the methods of beneficiating and processing, and the nature of the products that can be made are now readily ascertainable. The new knowledge of clay mineralogy has given rise to an improved clay mineral technology.

These accomplishments of the State Geological Survey were made possible through the employment of competent scientists and the use of powerful petrographic microscopes, X-ray and spectrograph, thermal analysis apparatus, and other specialized equipment.

21. A *complete inventory of clay and shale resources* of the State is the eventual goal of a long-range undertaking of the Survey. Samples of clays and shales are continually being collected and subjected to thorough analysis by the various techniques already described. The resulting information is classified and indexed and enables the Survey to guide operators in locating deposits of material having the particular characteristics required to meet industrial specifications. Such assistance was given this year to a clay products company which was seeking material suitable for the manufacture of a soft mud brick and to various companies searching for clays or shales for use in lightweight aggregate.

During the past year 131 samples of clay and shale from cores and outcrops, 9 samples of glacial till and loess, and 15 samples of miscellaneous clay materials were analyzed.

A special report on the high-grade clays in western Illinois is in preparation. Study of the field occurrences and the laboratory testing of samples have been completed and chapters on several counties have been written.

22. *The stability of earth material*—a critical factor in dam construction, in the erection of heavy industrial installations, and in the construction of airfield runways—is often directly related to its clay mineral content. The Geological Survey has been conducting special investigations on the behavior of different clay minerals under varying conditions of load and moisture. A confined compression machine built in the Survey shop is being used to determine the compressibility of nearly pure clay minerals with known water content and their sensitivity to compaction under deposition or under increased load.

Rock and Rock Products

Approximately four hundred plants operated in Illinois in 1952 and produced rock products valued at an estimated 63 million dollars. These include limestone and dolomite, lime, cement, silica sand, ground silica sand, and sand and gravel.

23. *Millions of tons of stone* is produced in Illinois each year, and the Geological Survey renders valuable assistance to operators and landowners by furnishing information on the extent, thickness, and quality

The adaptability of clays to modern ceramic techniques is tested in part with this laboratory-size machine for extruding brick.

Differential thermal analysis apparatus helps to identify some minerals which undergo certain physical changes at high temperatures.

of the rock formations of the State. During 1952, nearly 14,000,000 tons of limestone and dolomite were produced for a variety of uses, including building and road materials, liming of soil, the manufacture of lime and cement, and flux-stone for the steel industry. One major industrial company is enlarging its plant with the intent to produce an estimated 1,250,000 tons of stone per year from an adjacent underground mine originally opened on the basis of the Geological Survey's chemical stratigraphic studies along the Mississippi River southeast of St. Louis.

During the past year the Survey has been requested to supply data on limestone and dolomite resources in the Chicago area, in Macoupin, Greene, Calhoun, Madison, Jersey, Perry, Fulton, Kankakee, Warren, Effingham, Vermilion, and Jo Daviess counties. Service of this sort is made possible only by collecting and interpreting accurate data over a long period of years. It not only helps landowners and operators, but is instrumental in bringing new industries into the State.

24. *The physical and chemical nature of limestone and dolomite* is the subject of fundamental research being carried on in the Survey's laboratories to obtain a better understanding of the changes that take

Loading limestone in a large Illinois quarry which produces rock for concrete aggregate, road material, agricultural limestone, and other purposes.

X-ray equipment is used in analyzing crystal and molecular structure of minerals and in identifying them.

place either in the weathering of the stone or in the course of industrial processing. Data developed from such studies are needed to meet the new refinements of commercial specifications.

Systematic sampling and analysis of the commercial limestone of the State is in progress. During the past year a suite of samples obtained from a relatively new quarry in Johnson County offered the opportunity to secure accurate chemical data on an unusually great thickness of the particular formation exposed. Chemical analysis and insoluble residue determination revealed that, although the formation was not of high chemical purity, it was satisfactory for agricultural limestone.

In response to numerous requests from operators for information on the occurrence and chemical composition of the Platteville-Galena formation in LaSalle County, two of the three principal outcrops of this formation in the area were sampled bed by bed and the resulting 72 samples were analyzed for lime and magnesia content and for insoluble residue. One of the outcrops contained a thickness of 14 feet of stone sufficiently low in magnesium carbonate to be acceptable raw material for portland cement manufacture, and the other contained twenty feet of such stone. The stone is also of high quality for agricultural limestone. Examination of a limestone in Kendall County reported to be a high-calcium stone revealed that, although the formation contained some beds of high-calcium stone, the strata as a whole are too impure to be a commercial source of high-calcium stone.

The kind and amount of trace elements such as zinc, copper, manganese, boron, cobalt, and iodine in limestones and dolomites used for agricultural limestone and in mineral feeds for stock are of growing significance in plant and animal nutrition. From a quarry in Kankakee County, a group of 16 samples was selected for trace element content and to determine constancy of the trace elements both laterally and vertically. A group of 16 samples was also taken from the plant's production for one day, to check against the quarry-face samples.

Studies have been continued on the water-soluble salts which occur in Illinois limestone and dolomite either as solids between the crystals of the rock or in minute fluid inclusions within the crystals. The results of this work will relate to the reaction of limestone and dolomite during lime burning and to their properties as whiting and building stones.

25. *Agricultural limestone* is essential to the maintenance of soils, and Illinois produced more than 3,000,000 tons of stone for this purpose in 1952. During the year the Geological Survey tested many samples of stone submitted by county farm advisors, operators, and landowners and reported promptly on the quality of the stone for agricultural purposes.

26. *The siliceous materials of southern Illinois* are the subject of a report completed during the past year and now in press. The report deals with the resources, chemical and physical characteristics, and uses of a group of earth materials which for the most part occur in the State

only in extreme southern Illinois. They include silica (tripoli), novaculite gravel, calico rock, ganister, and chert gravel. Some of these are of commercial importance and others have potentialities. This publication will constitute the first comprehensive report on these particular resources and will be welcomed by the industry, especially by the producers of "amorphous" silica.

27. *Recent interest in deposits of sand and silt* in extreme southern Illinois as potential sources of moulding sands and fine aggregate for concrete has prompted a special study of these materials. Thirty samples were tested to determine particle size, distribution, and clay content. Chemical analyses of crude sand and various size fractions were made. It appears that judicious selection of deposits and suitable processing of the sands will make possible the production of fine aggregate for concrete, natural bonded and steel moulding sand, sand for the new process of "shell moulding," and silt for natural abrasives.

28. *Information on sand and gravel resources* in Illinois is in continuing demand, and during the year the Survey has assisted operators throughout the State in locating and testing deposits of sand or gravel having the particular properties needed for various uses.

29. *Research on the chemistry of silicate melts* (mixtures of lime, magnesia, alumina, and silica at high temperatures), particularly those which are or may be derived from rocks and minerals commercially mined or quarried in Illinois, in the Survey's geochemistry laboratories is being directed toward acquiring fundamental information applicable to industrial problems in the manufacture of mineral wool, ceramic products, pig iron, and steel. Current work is principally the investigation of the effect of fluorspar on the viscosity and surface tension of enamel melt. Results are made available by publication and by conferences with representatives from the industry concerned.

Fluorspar

As a result of the continued high demand for fluorspar, hydrofluoric acid, and products derived from it, the value of fluorspar produced in Illinois during 1952 remained at the same high level established during 1951. It is estimated that approximately 207,000 tons of fluorspar valued at $9,522,000 was produced in Illinois in 1952. More than half of the spar produced in the United States comes from the Hardin-Pope county area of southeastern Illinois. Although still in demand as a flux in the manufacture of steel (formerly its chief use) nearly half the fluorspar produced in Illinois now finds its way to an ever-expanding market in the chemical industry, where it is used for widely diversified purposes including the manufacture of refrigerants, insecticides, aviation gasoline, fluor-carbon plastics; in medical research; and in the development of

atomic energy. There has been an active market this year for all of the spar mined.

30. *The geology of fluorspar deposits* has been the subject of investigation by the Survey for many years. In April of 1952 a comprehensive bulletin on the subject was published by the Survey and has been enthusiastically received by the industry. Survey geologists continue to cooperate closely with the operators by interpreting results of core testing and by guiding exploration for new deposits. During the current year much valuable assistance has been rendered and in several instances has contributed to the discovery of additional deposits.

31. *The chemistry of fluorine and fluorine compounds* is a highly specialized field of research in which the Illinois Geological Survey has achieved wide recognition. Representatives of various types or classes of compounds are synthesized and their properties studied for application in various fields, the primary objective being to develop more diversified use of Illinois spar as a chemical raw material. Many important applications of the results of this work have already been made, one rare fluorine compound produced in the Survey's laboratories having contributed to the early success of the Manhattan Project.

Mine and mill of Rosiclare Lead and Fluorspar Mining Co. in Hardin County, southern Illinois.

A contract between the University of Illinois and the U. S. Air Force for the synthesis of organic fluorine compounds for fungicidal purposes was renewed for the current year. The Survey has also cooperated with two well-known institutions on cancer research (one, the University of Wisconsin Medical School, the other, the Radium Institute of Paris, France) by furnishing samples of organic fluorine compounds for studying the mechanism of cancer growth as induced by certain carcinogenic chemicals. Samples of compounds have also been furnished to plant pathologists of the Natural History Survey for studies on soil sterilization and gladiolus bulb treatment.

Zinc and Lead

In 1952 Illinois produced about 19,800 tons of zinc valued at $6,000,537 and 4,280 tons of lead valued at approximately $1,369,000. The old lead and zinc mining area around Galena in northwestern Illinois, so important in the early development of this part of the Middle West during and after the Civil War but virtually abandoned around the turn of the century, has been the scene of renewed and

Head frame for bringing zinc ore to the surface at a northwestern Illinois mine and plant for separating ore from waste rock.

profitable mining activity as a result of the Geological Survey's geological assistance in exploration since 1943, when wartime need for these minerals was great. The Survey's work encouraged new prospecting in the area, and in recent years a thriving mining industry has grown up.

32. *Practical assistance to prospectors and operators* is rendered from a field office at Galena where a small staff is stationed. Survey geologists carry on active field investigation and research, study and interpret cores and drill cuttings, and personally confer with operators and individuals concerned with mining developments. During the year covered by this report, cuttings from 152 prospect drillings and five water wells were studied. Sixty-four of the prospect borings contained significant quantities of mineral, and estimates were made of the amount of zinc, lead, and iron in these borings. More than 110 conferences were held with members of the northwestern Illinois mining industry and some 150 conferences were held with landowners and individuals interested in zinc and lead resources.

33. *Maps and cross sections* are prepared for public reference. Two geological cross sections of the principal mineralized belt and a large geologic structure contour map of the area are accessible to the public at the Galena office. The cross sections show the surface topography, sequence of formations, and the position of the ore bodies, and serve to show the layman the shallowness of the ore-bearing structures, the lack of correlation between surface topography and bedrock structure, and what formations are related to the ore deposits. A series of base maps covering the district, on a scale of 500 feet to 1 inch, shows the location of all prospect borings and water wells, including property boundaries and identification number of the borings.

34. *The geology of the ore deposits* receives continuous study. Mines in the area reveal several types of ore bodies, and Survey geologists study the deposits in place in the mines and make microscopic examinations of ore samples in order to interpret and evaluate the complex relationships of mineralized zones. A study is currently in progress on the regional relations and variations in thickness and dolomitization previous to the episode of mineralization. A study is also being made of the sequence of deposition of the minerals of the ore body.

Groundwater Resources

The need for water is universal, and the problems associated with its presence or absence underground are primarily geological. The search for underground water constitutes an activity to which the Geological Survey gives constant attention. A staff of eight geologists gives full-time service to this problem.

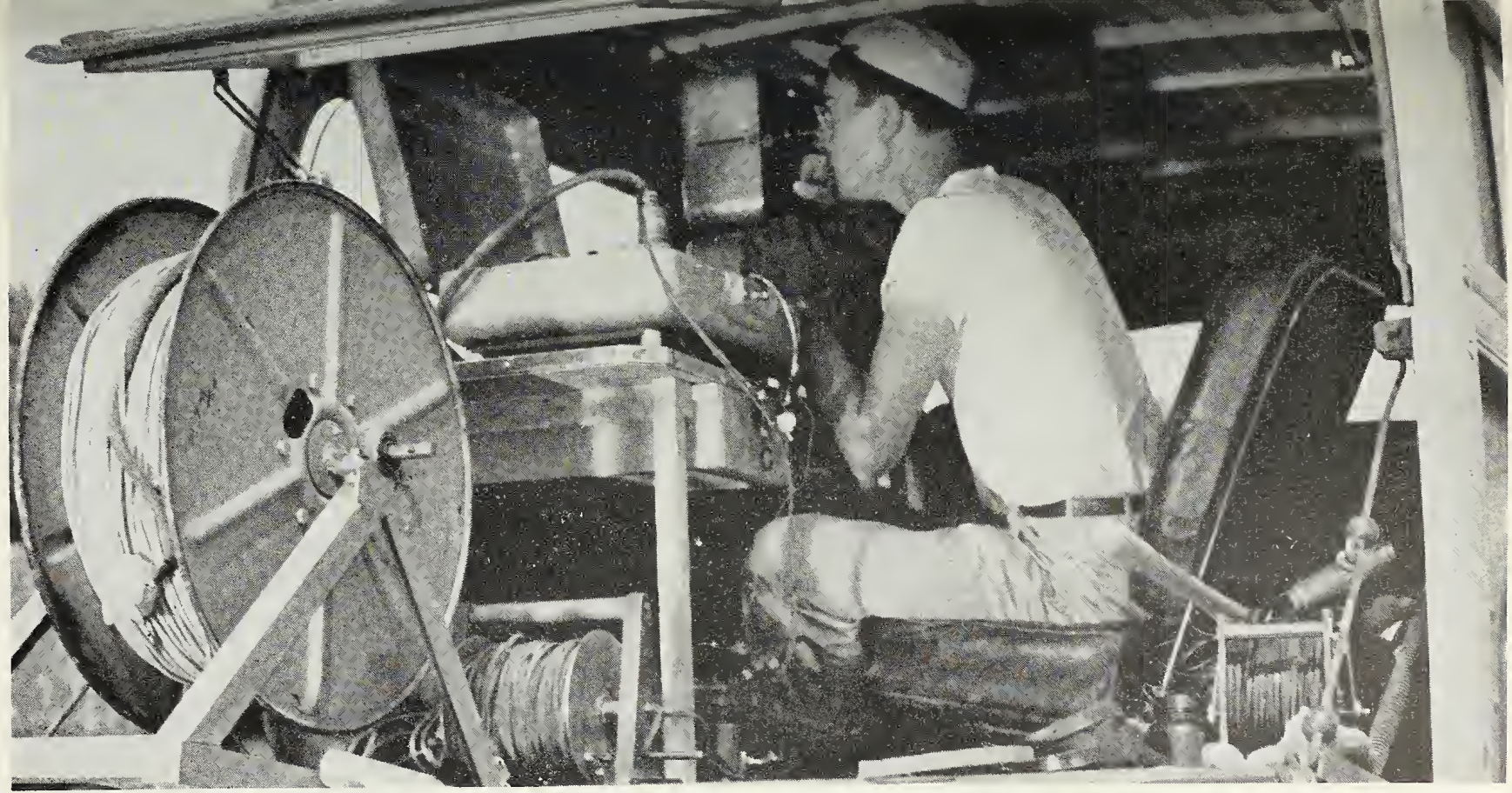
35. *Special reports* are prepared on the geology of specific localities where water is needed. These reports tell the driller or landowner what kind of rocks underlie the area, in which of them water is likely to occur, and at what depth it will probably be found. During the past year 242 such reports were prepared, of which 113 were for private citizens, 37 for industrial installations, 46 for municipalities, and 46 for public institutions. In addition some 54 technical and geophysical problems were handled by correspondence, and numerous conferences were held with individuals or groups concerned with technical problems relating to groundwater.

36. *Field and laboratory studies* relating directly to groundwater resources are in progress. Special geologic study of the East St. Louis area and another of Lee and Whiteside counties are being pursued, and during the past year similar investigations have been undertaken of the Rock River Valley in Winnebago County and of groundwater resources in southern Crawford County.

37. *Geological interpretation of results of test drilling* is made by Survey geologists through the microscopic examination of drill cuttings and the mechanical analysis of sand, to assist drillers in the evaluation of their testing.

38. *Electrical resistivity surveys* are made to discover the location of underlying gravel deposits which might carry large quantities of water. The Survey pioneered in this method of locating water supplies, which has proved very effective in directing the placement of test holes and has saved much needless and expensive testing in barren areas. During the past year 47 such surveys were made, the largest number ever made by the Geological Survey in one year. They included 20 for municipalities, 13 for private individuals, 11 for industries, and 3 for schools. Among the surveys made were those for a water supply for the National Petrochemical Corporation in Douglas and Champaign counties; water supplies for Scott Air Force Base in St. Clair County and Chanute Field in Champaign County for the U. S. Corp of Engineers; and two surveys for water supplies for secondary recovery operations in oil fields near Casey in Cumberland County.

39. *Cooperation with the Illinois Water Well Drillers Association* has been continued, a member of the staff serving as executive secretary of the Association. The Geological Survey cooperated in the foundation of this Association in 1927 and has continued active cooperation by visiting the operations of water well drillers, supplying them with sample sacks and log books, collecting well samples from them, and otherwise aiding them in water-supply development.



A small refraction seismograph is used to determine depth to bedrock and other subsurface geological conditions where no drilling records are available. The operator is about to set off a small charge of dynamite by remote control. The resulting shock waves will be recorded on photographic paper and then interpreted. Such information is needed to help find groundwater resources and solve foundation problems in engineering.

Geophysical Research

40. *The use of radio wave transmission through rock formations* as a research tool was developed by the Geologieal Survey and was made known through a circular published in 1950. A more comprehensive and complete report on this work is now in press. During the past year a 140-mile traverse was made along the Wabash and Ohio rivers between Vincennes, Indiana, and Golconda, Illinois, to check the usefulness of the method for geologie mapping. Analysis of the field data is now in progress.

41. *Creating miniature earthquakes* by exploding small charges of dynamite at shallow dcpths (6 or 7 feet) and recording the course, intensity, and speed of the waves on a small refraction seismograph is another modern scientific method of securing geologic information regarding rock formations and their structure beneath the surface. Preliminary seismic traverses indicate satisfactory determinations of depth to bedrock, and that this method can be employed in areas where the bedrock surface is completely obscurcd. It will be of special value used in conjunction with electrical resistivity surveys in delineating the course of buried bedrock valleys which may contain sand and gravel deposits bearing abundant groundwater. Research will be continued on the application of seismological techniques to other types of geologic exploration.

42. *New apparatus for earth resistivity measurement* has been designed in the Survey's geophysical laboratory and represents appreciable technologic improvement over apparatus previously used. Two such instruments are currently under construction.

Engineering Geology

Geological conditions are frequently the determining factor in engineering problems encountered in highway construction, in the selection of suitable sites for reservoirs and dams, in testing the stability of earth materials for foundations for large structures, and in determining the character and strength of rock strata as it may affect the planning of underground excavation. The Survey's Engineering Geology Division cooperates with Federal and with other State agencies on problems of this type.

43. *Geological information relating to engineering problems* is furnished through field and office conferenees and correspondence. Where necessary, earth materials are sampled and studied and reports are prepared. During the year this type of cooperation was extended to

the State Division of Highways in connection with the Illinois Cooperative Highway Research Program; to the State Department of Conservation in connection with its new program of recreational lakes and with particular reference to geological conditions at Spring Lake in Tazewell County, and proposed dam sites at Red Hills State Park in Lawrence County and Siloam Springs State Park in Adams County; to the U. S. Corps of Engineers regarding information on Big Muddy River in southern Illinois and on geological conditions in the Villa Grove area; to the U. S. District Engineer's office in Chicago regarding the effect of coal mining under the proposed route of a new water main from Belleville to Scott Field; and to the U. S. Geological Survey, Water Resources Branch, concerning the glacial geology of parts of the State as it affects runoff and stream flow.

As a matter of policy the Geological Survey restricts its assistance to furnishing geologic information basic to the engineering aspect of the problems which are brought to it and avoids competing with private engineering consulting practice. This type of help is frequently requested by consulting engineers who have been engaged on problems requiring geological information for their solution. During the current year the assistance of the Survey's Engineering Geology Division has been sought repeatedly in connection with proposed underground storage projects.

Assistance was also rendered to the town of Vienna in Johnson County in connection with the proposed reservoir site, as well as information on depth to bedrock for a new sewer system; to the Sangamon County Farm Bureau regarding a dam site in Sangamon County; to a firm of consulting engineers regarding geologic conditions along a proposed access road to the Illinois Security Hospital northwest of Chester; to a large corporation in Chicago with respect to foundation conditions for a proposed institutional structure; and to various organizations or individuals regarding dams, small lakes, and other projects.

Research and Mineral Resource Records

Many practical problems related to the discovery and development of mineral resources owe their solution to long-range, patient research of a basic nature in geology, chemistry, and physics carried on in the field and laboratory through the years.

44. *Microscopic examination of drill cuttings* from wells and test holes reveals the identity, character, thickness, and extent of rock formations deep underground. Data from these studies are of inestimable value in the correlation of rock strata in connection with the search for oil and gas, coal, and other valuable mineral deposits, and the Survey is

Microscopic study of drill cuttings reveals the nature and succession of underground rock formations. Work of this type is essential to the discovery of mineral deposits.

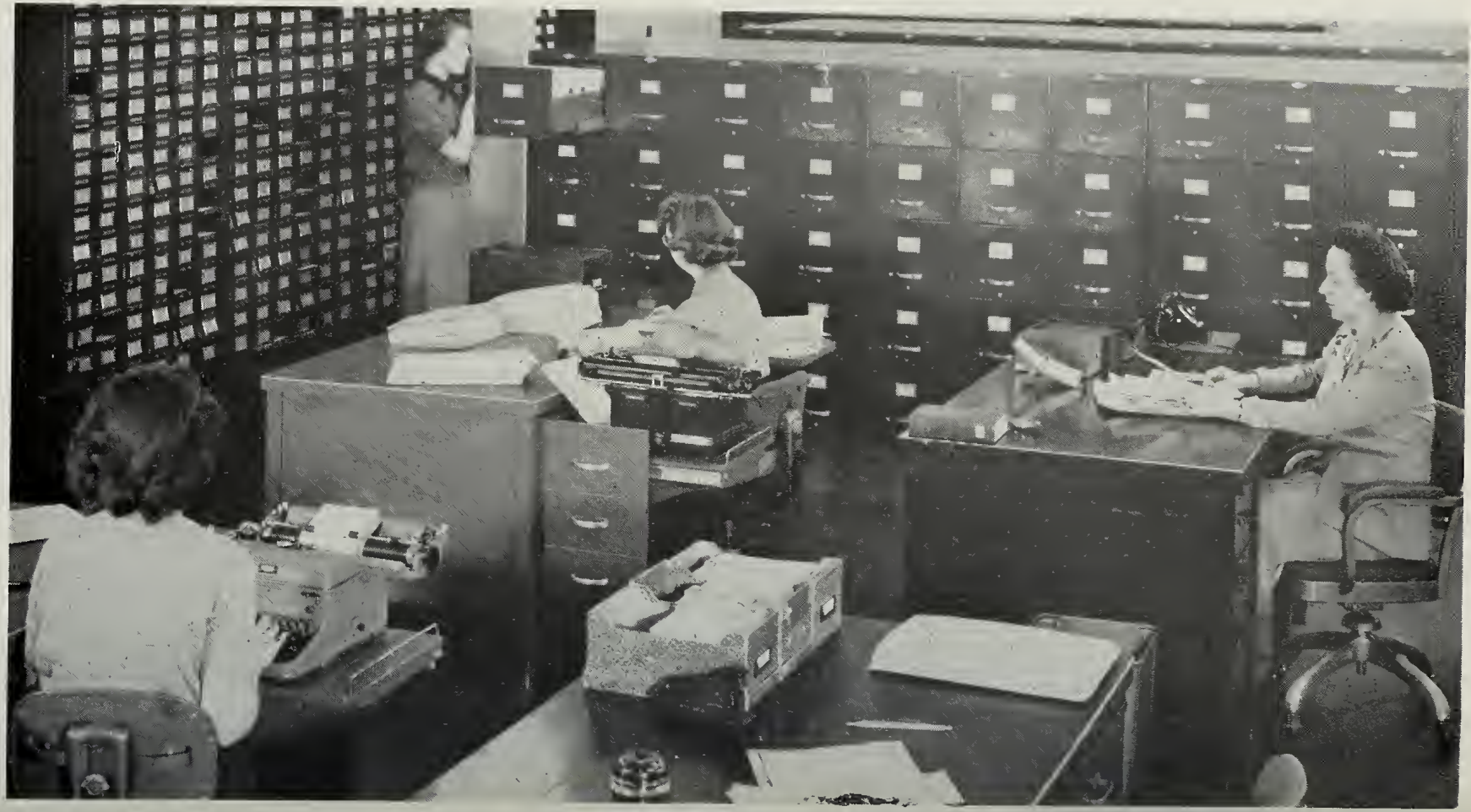
continually called upon for the interpretation of well records. During the past year 32,365 samples from 421 wells, representing a total footage of 152,210 (approximately 29 miles), were studied and described in the Survey's "subsurface" laboratory. In addition to the drill cuttings, cores from 46 wells, having a total footage of 7,174 feet, were examined microscopically, recorded, and filed. Sample study logs of the wells and cores are prepared and furnished to the operators, and copies are placed in the Survey's files. The samples themselves are labeled, assembled into sets corresponding to each well log, and systematically filed. More than a thousand such sets from as many wells were filed during the past year, bringing the total number of samples sets on file to more than 23,200.

45. *Accurate correlation of rock strata* — essential to informed exploration for mineral deposits — depends upon studies such as those just described and also on field examination of rock formations where they are exposed at the surface, the identification of animal or plant fossils which they contain, recognition and evaluation of lithological features, and other investigations which can be adequately carried on only by highly trained geologists. During the past year considerable study has been given to rock formations of Ordovician age, in which the zinc and lead deposits of northwestern Illinois occur, and to Silurian strata which contain fossil coral reefs of particular interest as sites for the accumulation of oil and gas. Continued study has been given to a five-inch core from a test hole drilled to a depth of several thousand feet through formations which do not come to the surface in that part of Illinois. Possession of this core for study by Survey geologists is of particular significance because of the growing interest in the possibility of oil production from deeper strata. Detailed correlation studies have also been in progress on formations of the Mississippian age in which are found the most productive oil sands.

Special field and laboratory studies have also been made of Pleistocene deposits which are of particular significance in connection with sand and gravel production and groundwater resources.

46. *Spectrographic analysis of rock and mineral samples* is another modern and highly specialized laboratory method being used by the Survey to determine and identify minute amounts of mineral substances which frequently have an important bearing on the properties and use of the rocks in which they occur. The importance of certain trace elements in limestone has already been mentioned. During the past year 43 samples of limestone have been analyzed, 30 quantitatively and 13 qualitatively.

In recent months, also, special attention has been given to spectrographic methods for determining the amount of germanium in Illinois



A part of the Mineral Resource Records room, where the logs of oil and water wells and other data on the mineral resources of the State are carefully filed for ready reference.

Spectrochemical analyses of minerals are made by a highly trained physicist in spectroscopy.

coals and in coal fly ash. There is current demand for this rare element for use in certain sections of the electrical industry. Results indicate that germanium is present in the fly ash obtained from some Illinois coals in amount sufficient for consideration as a commercial source.

47. *The Analytical Chemistry Division* of the Survey works hand-in-hand with the geologists, other chemists, and physicists of the staff, furnishing detailed chemical data essential to many aspects of the Survey's work. During the period covered by this report, 2,362 analyses were made on 1,022 samples of coal and coke (349 of which were for the State Department of Purchases and Supplies), 151 samples of rock, 92 samples of brine, 76 samples of gas, and 4 samples of oil. In addition some 136 samples were analyzed in the special microchemical laboratory.

48. *The usefulness of research data* depends in large part on its being readily and permanently accessible for continuing reference use. A special Mineral Resource Records Division, staffed by eight full-time persons, devotes its entire time to the systematic cataloging and filing of technical research data. These files contain more than 128,000 well log records, 30,000 electric logs, some 3,700 lantern slides, and other valuable research material including manuscripts and field notes. The

Division also maintains a special map library which is continually growing. Approximately 5,000 geologic and special maps are filed here in addition to 10,000 topographic maps, 1,000 of which were received during the past year.

The Geochemical Section of the Survey has in its files chemical analyses of 17,574 samples, which include: coal, 9,989; rock, 3,794; gas, 857; oil, 479; brine, 1,383; and microanalyses, 1,072.

Mineral Economics

The economic trend and competitive factors in mineral production, transportation, and marketing are critical in industrial development. Through the work of a mineral economist with a small staff of assistants to compile data for analyzing these problems, the Survey furnishes economic information to mineral operators, producers, manufacturers, railroads, chambers of commerce, and financial organizations throughout the State.

49. *Fuels used in the Chicago industrial district* were the subject of special study during the past year, and a report presented at the regional meeting of the American Institute of Metallurgical Engineers will be published by that organization.

50. *Movements in fuel prices* are currently receiving study and a report is in preparation which will include, in addition to a discussion of natural gas markets and consumption in Illinois, information on changes in the price structure of coal and fuel oil.

51. *Special reports* have also been prepared on mineral resources in the industrial development of the Middle West, a paper on this subject having been presented before the American Association for the Advancement of Science in December 1952; and on the fundamentals of mineral conservation, a report which will be published for the information of teachers in Illinois schools.

52. *Annual reports on the Illinois mineral industry* are prepared which give statistics of production and interpretation of them. This work is carried on with the cooperation of the U. S. Bureau of Mines, the U. S. Bureau of the Census, and the State Department of Mines and Minerals. These reports, the first of which was published in 1931, constitute an uninterrupted record of Illinois mineral industry since that date.

Topographic Mapping

53. *Topographic maps for 95 per cent of the State's area* have now been prepared as the result of a systematic program of mapping which is carried forward each year in cooperation with the U. S. Geological

Survey. Through the progressive attitude of Illinois legislators in regularly appropriating funds to carry on this work (funds so appropriated are matched dollar for dollar by the Federal government), this ambitious and very important project is nearing completion. It is anticipated that, at the current rate, the first topographic mapping of the entire State will be completed in four years.

During the past year, 828 square miles of territory, including 71 square miles of revision, were mapped topographically in the field or photogrammetrically on a scale of 1 inch to a mile, 36 square miles of territory were mapped topographically in the field on a scale of 2½ inches to a mile, and planimetric maps to serve as bases for topographic mapping were made for five quadrangles, on the cooperative program.

In addition, the U. S. Geological Survey with noncooperative Federal funds mapped topographically in the field 782 square miles of territory on a scale of 1 inch to a mile, mapped photogrammetrically 4 square miles on a scale of 2½ inches to a mile, made photogrammetrically preliminary topographic maps for 8 complete and parts of 3 quadrangles on a scale of 2½ inches to a mile, revised photogrammetrically the mapping of 20 quadrangles on a scale of 2½ inches to a mile, and made planimetric bases for topographic mapping for 2 quadrangles on a scale of 1 inch to a mile and for 10 quadrangles on a scale of 2½ inches to a mile. Also, a considerable amount of horizontal and vertical control was run in preparation for topographic sketching.

Five new quadrangle maps on a scale of 1 inch to a mile, one new quadrangle map on a scale of 2½ inches to a mile, and reprints of 5 quadrangle maps on a scale of 1 inch to a mile and of 5 quadrangle maps on a scale of 2½ inches to a mile were published by the Federal Survey during the past year.

Public Service and Educational Extension

54. *Public information.* The State Geological Survey gives careful attention to every inquiry received whether it be from a pupil in the school, from a Boy Scout working on a merit badge, or from a large industrial corporation. Thousands of requests are received every year and each one is handled by the staff member best equipped to furnish the information desired. The Survey's files contain hundreds of letters from individual citizens, from mineral operators, school teachers, chambers of commerce, village and city councils, and large industrial organizations expressing appreciation of the prompt and courteous service received from their State Geological Survey. These letters in themselves are a rich reward for the pains taken.

55. *Educational extension.* For the past 24 years a special division of the Geological Survey has been rendering educational extension service throughout the State. This service includes the organization and leadership of field study conferences for science teachers; free identification of mineral specimens; informative correspondence with teachers and citizens; occasional lectures to organizations; publication of popular educational pamphlets; the distribution of free rock-and-mineral collections to schools; and educational exhibits at State and County fairs and special scientific meetings. Every effort is made to assist the science teachers of the secondary and even primary schools of the State in the technical and cultural education of our young people.

During the past year 285 sets of typical rocks and minerals were distributed to schools, scout troops, nature clubs, and other civic organizations throughout the State.

Field conferences primarily designed for science teachers but open to all interested persons were held in 6 widely separated areas. Mimeographed guide leaflets are prepared for each trip and there are now some 41 such reports available to teachers, students, and citizens. In addition to these regularly scheduled trips, members of the Geological Survey's Educational Extension Division conducted 7 special field conferences at the request of various science clubs, local geologic societies, and teachers college training programs. Six special lectures were given to conservation workshops, local nature study clubs, and professional societies.

RESEARCH FACILITIES

The physical facilities of the Survey for research on mineral resources are probably not excelled in any comparable institution. The following is a summary of the laboratories:

Geological Resources Section

Five laboratories for coal research: one in mining geology; one for megascopic, microscopic, and thermal analytical studies of coal; two for paleobotanical research on the botanical constituents of coal; and one for the study of Pennsylvanian stratigraphy and the preparation of coal-resource maps.

One laboratory for petroleum engineering research for studies of fluid flow through porous media and related problems.

Four laboratories for the study of industrial minerals: one moulding-sand laboratory for testing moulding sands and clays for bonding moulding sands; one for fundamental research on the basic mineralogy

of dolomites and limestones; one for studies of the character, composition, and uses of limestone, dolomite, sand, gravel, silica, and other industrial minerals; and one for the microscopic study of zinc, lead, and fluorspar ores and of limestone, dolomite, and other industrial minerals.

Four laboratories for research on clays and clay mineral technology: two for differential thermal analyses; and two for testing the physical properties of clays in relation to soil mechanics, ceramic utilization, recovery of petroleum, and other engineering problems.

One laboratory for research in geophysics and on geophysical equipment, including apparatus for electrical resistivity surveys, radio transmission through geological formations and seismic surveys; also used for research on samples from water wells.

Three laboratories for research in stratigraphy and areal geology: one subsurface-geology laboratory for the study of samples of drill cuttings and preparation and study of insoluble residues from calcareous rocks; one laboratory for the study of diamond drill cores and the composition of rocks; and one laboratory for paleontologic research involving the identification of fossils and their use in stratigraphy.

Three rooms are equipped with apparatus used in the preparation of rocks, diamond drill cores, and well cuttings for research studies.

Geochemical Section

Six analytical laboratories: one devoted to analysis of coal purchased by the institutions of the State; one for analysis of coal, coke, and char in research on Illinois coals; one for analysis of rocks and brines; one for the study of oil sands and composition and properties of petroleum and natural gas; one for the determination of the heat value of coal; and one for determination of nitrogen in connection with coal analysis.

One microanalytical laboratory for rapid analysis of materials when very small samples are used.

Two research laboratories for the fundamental study of the chemical nature of coal.

Three laboratories for the study of the physical and chemical properties of silicate materials at high temperature, surface properties of coal, coke, and char, and factors that affect efflorescent coating of building brick.

Two laboratories devoted to the study of organic fluorine compounds derived from fluorspar, deposits of which, in southern Illinois, are unique and rank first in production in the Western Hemisphere.

One X-ray laboratory for mineral identification and for study of atomic and molecular structure of minerals.

Three spectrographic laboratories for determining constituents present in trace amounts in minerals and rocks, including petroleum and petroleum products, coal, liquefied coal products, and new laboratory compounds.

One laboratory equipped with two armored cubicles in which experiments requiring special precaution from explosion are carried out.

One furnace room with electric and gas furnaces for ashing of coals, stabilization of precipitates in analytical work, investigation of chemical changes that take place in rocks and minerals when treated at various temperatures, and for the study of other temperature phenomena.

Two rooms for the preparation and drying of coal samples for analysis.

One small shop room equipped for use by the laboratory staff.

Experimental Laboratory Building

A special laboratory building, built in 1941, located near the University Power Plant, is used for the study on pilot-plant scale of the coke and char potentialities of Illinois coals and of the combustion characteristics of Illinois stoker coal. Equipment used in coking studies includes a pilot oven operated since 1944 which is designed to produce coke under semi-commercial heating conditions for evaluation of its physical and chemical properties, and a second oven, recently completed, for determining the extent of pressures exerted on coke oven walls during carbonization. This building also has a small machine shop for work in connection with maintenance of research equipment in the building.

Machine Shop

The Survey possesses a specially equipped machine shop in the Natural Resources Garage for the design and construction of research apparatus not available on the open market. The equipment includes one No. 2 milling machine, one modern lathe for moderately heavy work, one small lathe for light work, four drill presses of assorted sizes, and other accessory apparatus for the construction of instruments and specialized research apparatus.

Modern Research Apparatus

The equipment of the Survey's research laboratories includes, among other things, certain distinctive and specialized items, such as high-powered microscopes, X-ray, spectrographs, Geiger counters, high-pressure equipment, photoelectric potentiometers, infra-red spectro-

photometer, electronic photometer and photomultiplier, graphic recorders, refraction seismic equipment, earth resistivity equipment, special instruments for the study of radio wave transmission through geological formations, differential thermal analysis units, low-temperature fractional gas distillation equipment, apparatus for measuring gas absorption on solids, heat-of-wetting equipment, surface tension equipment, ultrasonic generators, viscosimeters, well depth measuring equipment, and many other unusual devices for obtaining important factual information on the mineral resources of the State.

ADMINISTRATIVE, SCIENTIFIC, AND TECHNICAL PERSONNEL

The key to creative research is the scientist. Careful attention has been given to the selection of research personnel to meet the high scientific standards of the Survey. Space does not permit the listing of all the scientific personnel of the State Geological Survey but there is given below the administrative, scientific, and technical personnel who direct the research and public service activities of the Survey.

Office of the Chief

M. M. Leighton, Chief; B.S., U. of Iowa, 1912, M.S., 1913; Ph.D., U. of Chicago, 1916. Member of Iowa Geological Survey, summers of 1914 and 1915; faculty member of State U. of Wash., 1915-16; U. of Chicago, summer 1916; Iowa State Teachers College, 1916-17; State U. of Wash. (also Washington Geological Survey), 1917-18; Ohio State U., 1918-19; U. of Illinois (also State Geological Survey), 1919-23; Member of Ill. State Museum Board, 1937-; Vice Chairman Post-War Planning Commission, 1945-47; Member Advisory Committee to U. S. Geol. Survey, 1943-; Chief, Ill. State Geol. Survey, 1923-.

Enid Townley, Geologist and Assistant to the Chief; B.S., U. of Chicago, 1921, M.S., 1925. Midwest Refining Co., 1922; staff, Wellesley College, 1922-24; Guide Lecturer, Chicago Academy of Sciences, 1926-27; Geologist, Pure Oil Co., 1927-31; Geologist and Assistant to the Chief, Ill. State Geol. Survey, 1931-.

Gilbert O. Raasch, Geologist in Charge, Educational Extension; B.A., U. of Wisconsin, 1929, Ph.D., 1946. Curator, Wis. Geological Museum, 1929-36; Magnolia Petroleum Corp., 1936-37; Darby Petrol, 1937-38; Milwaukee Public Museum, 1940-42; Major, Air Force, 1942-46; Ill. State Geol. Survey, 1946-.

Vivian Gordon, Head, Mineral Resource Records; Skelly Oil Co., 1937-42; Exec. Sec., Land and Production Dept., Globe Oil and Refining Co., 1942-46; Ill. State Geol. Survey, 1946-.

Anne E. Kovanda, Librarian; B.S., U. of Ill., 1937, B.L.S., 1942. Staff, U. of Ill. Journalism Library, 1941-42; Detroit Public Library, Technology Department, 1942-47; Ill. State Geol. Survey, 1947-.

Jane V. Olson, Associate Technical Editor; B.A., U. of New Mexico, 1939. Staff Museum of New Mexico, 1939-40; Commerce Clearing House, 1941; Peabody Museum, Harvard U., 1942-43; Atlantic Monthly Co., 1943-46; Conde Nast Publications, Inc., 1946-49; Ill. State Geol. Survey, 1949-.

Geological Resources Section

Arthur Bevan, Principal Geologist in Charge of Geological Resources Section, and Acting Head of Coal Division; B.S., Ohio Wesleyan U., 1912, Sc.D., 1942; Ph.D., U. of Chicago, 1921. Faculty member, Ohio Wesleyan U., 1912-14 (acting Head Dept. of Geol. 1913-14); Ohio State U., 1917-19; State U. of Montana, 1919-21 (also Montana Bureau of Mines, summers 1919-22); U. of Ill., 1921-29; U. of Chicago, summer 1924; Ill. State Geol. Survey, summers 1923-29; State Geologist of Virginia, 1929-47; Chairman, Division of Geology and Geography, National Research Council, 1946-49; Principal Geologist, Ill. State Geol. Survey, 1947-.

J. E. Lamar, Geologist and Head, Industrial Minerals Division; B.S., U. of Chicago, 1920; Ill. State Geol. Survey, 1920-.

A. H. Bell, Geologist and Head of Oil and Gas Division; B.A., U. of Toronto, 1917; Ph.D., U. of Chicago, 1926. Scholar, National Research Council of Canada, 1920-21; Geological Survey of Canada, 1914, 1920-23; Texas Co., 1924-26; Ill. State Geol. Survey, 1926-.

George E. Ekblaw, Geologist and Head, Engineering Geology and Topographic Mapping; A.B., U. of Ill., 1922, A.M., 1923; Ph.D., Stanford U., 1927. Ill. State Geol. Survey, 1920-25; 1927-.

H. B. Willman, Geologist and Head, Stratigraphy and Areal Geology; A.B., U. of Ill., 1926, M.A., 1928, Ph.D., 1931. Kentucky Geol. Survey, 1926; staff, U. of Ill., 1926-28; Ill. State Geol. Survey, 1927-.

Ralph E. Grim, Consulting Clay Mineralogist; Ph.B., Yale U., 1924; Ph.D., U. of Iowa, 1931. Staff, U. of Miss. and Miss. Geol. Survey, 1926-30; U. of Iowa, 1930-31; Ill. State Geol. Survey, 1931-50; U. of Ill., 1950-.

M. Wm. Pullen, Geologist and Head, Geophysical Research; B.A., Colgate U., 1938; M.S., Syracuse U., 1940; Ph.D., U. of Ill., 1950. Cunningham Oil Co., summers 1937, 1938. Staff, Syracuse U., 1938-40; U. of Ill., 1940-42; Ill. State Geol. Survey, 1942-.

Frank C. Foley, Geologist and Head of Groundwater Geology and Geophysical Exploration; B.A., U. of Toronto, 1929; Ph.D., Princeton U., 1938. Staff, Dartmouth College, 1929-30; Princeton U., 1930-33; U. of North Dakota, 1933-41; State Geologist, North Dakota Geological Survey, 1938-41; U. S. Geol. Survey, 1941-42 and 1946-51; Major, Corps of Engineers, 1942-45; Ill. State Geol. Survey and U. of Ill., 1951-.

Paul A. Witherspoon, Petroleum Engineer and Head of Petroleum Engineering Division; B.S., U. of Pittsburgh, 1941; M.S., U. of Kansas, 1951. Phillips Petroleum Co., 1941-49; U. of Kansas, 1949-51; Ill. State Geol. Survey, 1951-.

Geochemistry Section

Frank H. Reed, Chief Chemist; A.B., Wabash College, 1911; Ph.D., U. of Chicago, 1917. Staff, Wabash College, 1913-14; Mich. State College, 1914-15; Sherwin-Williams Co., 1917-19; Butterworth-Judson Corp., 1912-22; Supt., Chemical Plant, Tower Manufacturing Co., 1922-27; Chemical Dye & Mfg. Co., 1927-28; Plant Supervisor, National Aniline & Chemical Co., 1928-30; Roessler & Hoslacher Chemical Co., 1930-31; Scientific Consultant, Federal Economic Administration, Northwest Europe, 1945; Visiting expert to General MacArthur's Headquarters, Tokyo, December 1948-February 1949; Ill. State Geol. Survey, 1931-.

O. W. Rees, Chemist and Head, Analytical Chemistry; B.S., Earlham College, 1922; M.S., U. of Ill., 1925, Ph.D., 1931. Staff, Earlham College, 1922-24; Ill. State Water Survey, 1925-30; Ill. State Geol. Survey, 1931-.

G. C. Finger, Chemist and Head, Fluorine Chemistry; B.S., U. of Ill., 1927, M.S., 1928, Ph.D., 1938. Staff, Purdue U., 1928-30; U. of Ill., 1930-32; Ill. State Geol. Survey, 1933-.

W. F. Bradley, Chemist and Head, X-Ray Division; A.B., U. of Ill., 1930, Ph.D., 1935. Ill. State Geol. Survey, 1934-.

J. S. Machin, Chemist and Head, Physical Chemistry; A.B., Westminster College (Mo.), 1921; M.S., U. of Ill., 1922; Ph. D., U. of Chicago, 1932. Staff, Westminster College, 1922-24; Sioux Falls College, 1924-36; Ill. State Geol. Survey, 1936-.

G. R. Yohe, Chemist and Head, Coal Chemistry; B.A., Cornell College, 1925; M.S., U. of Ill., 1927, Ph.D., 1929. Goodyear Tire and Rubber Co., 1929-30; staff, Ohio Wesleyan U., 1930-37; Ill. State Geol. Survey, 1937-.

H. W. Jackman, Chemical Engineer and Head, Chemical Engineering; B.S.E., U. of Mich., 1923, M.S.E., 1924. Champion Spark Plug Co., 1924-25; Chief Chemist and Supt. of Manufacture, Battle Creek Gas Co., 1925-41; Ill. State Geol. Survey, 1942-.

KENNETH B. THOMSON, Physicist; B.A., U. of Western Ontario, 1923, M.A., 1924; Ph.D., U. of Mich., 1932. Alderson, Mackay & Armstrong, 1927-28; staff, Queens U. (Ontario), 1928-30; U. of Mich., 1930-31; Queens U., 1932-33; Cancer Research Lab., U. of Penna., 1933-34; U. of Mich. (Rockefeller Foundation Grant), 1934-36; National Smelting Co., 1937-48; National Spectrographic Laboratories, 1948; Ill. State Geol. Survey, 1949-.

Mineral Economics

W. H. VOSKUIL, Mineral Economist; B.S., U. of Wis., 1921, M.S., 1922, Ph.D., 1924. Staff, U. of Wis., 1922-24; Wharton School of Finance, U. of Penna., 1924-30; Chief Mineral Economist, National Industrial Conference Board, 1930-31; Mineral Economist, U. S. Bureau of Mines, 1931; Consultant, Office of Price Administration, 1941-42; Council of Foreign Relations, 1943; Ill. State Geol. Survey, 1931- and U. of Ill., 1949-.

In the Geological Resources Section, the full-time staff of the Coal Division numbers 11; Oil and Gas, 7; Petroleum Engineering, 2; Industrial Minerals, 5; Clay Resources and Clay Mineral Technology, 3; Groundwater Geology and Geophysical Exploration, 8; Geophysical Research, 3; Engineering Geology, 2; and Stratigraphy and Areal Geology, 10.

In the Geochemistry Section, the full-time staff of the Division of Coal Chemistry numbers 3; Physical Chemistry, 3; Fluorine Chemistry, 2; Chemical Engineering, 7; X-ray, 1; Spectrochemistry, 2; and Analytical Chemistry, 12.

The staff of Mineral Economics includes three persons.

The Survey has 9 research affiliates and 6 consultants, most of whom are faculty members of the University of Chicago, University of Illinois, Northwestern University, and University of Southern Illinois.

The Library staff includes 3, Mineral Resource Records Division, 8, and Editing and Publications, 4. An additional 26 persons handle photography, stenographic service, correspondence files, office information, financial records, mailing service, machine shop work, and maintenance of motor vehicles.

Twenty college students, most of them specializing in geology, are employed part-time as research and technical assistants.

Publications

Prompt publication of results obtained from research work is essential to its greatest effectiveness. Every effort is made by the Survey to bring its information to the citizens of the State as soon as possible consistent with accuracy.

Publications issued during the year include the following:

Bulletin:

77. Geology and Mineral Resources of the Carlinville Quadrangle: John R. Ball. 1952. 110 pp., 4 pls., 22 figs., 13 tables.

Physiography, stratigraphy, structure, geologic history, and mineral resources; includes 54 geologic sections and color plate showing surficial and economic geology and bedrock surface.

Reports of Investigations:

163. Viscosity Studies of System CaO-MgO-Al_2O_3-SiO_2: III, 35%, 45%, and 50% SiO_2: J. S. Machin, Tin Boo Yee, and D. L. Hanna. 1953. (Reprinted from Journal of the American Ceramic Society, vol. 35, no. 12, pp. 322-325, 1952). 9 pp., 3 figs., 3 tables.

In this continuation of previous papers on viscosity in the system CaO-MgO-Al_2O_3-SiO_2, data are presented for melts containing 35%, 45%, and 50% SiO_2 with varying percentages of the other three oxides that make up the system.

164. Water Soluble Salts in Limestones and Dolomites: J. E. Lamar and R. S. Shrode. 1953. (Reprinted from Economic Geology, vol. 48, pp. 97-112, 1953). 16 pp., 1 fig., 7 tables.

Reports the presence of minute but numerous fluid inclusions containing various salts in Illinois limestones and dolomites and points out their possible effect on the uses of these rocks, such as lime making.

167. Crystal Chemistry and Differential Thermal Effects of Dolomite: W. F. Bradley, J. F. Burst, and D. L. Graf. 1953. (Reprinted from the American Mineralogist, vol. 38, pp. 207-217, 1953). 11 pp., 6 figs., 2 tables.

Correlates the responses of dolomite crystals to heating with plastic deformation which they underwent during prolonged grinding.

Illinois Petroleum Series:

65. Developments in Illinois and Indiana in 1951: A. H. Bell and R. C. Cooper. 1952. (Reprinted from Bull. Am. Assoc. Petr. Geol., vol. 36, no. 6, pp. 1078-1090, 1952). 12 pp., 1 fig., 10 tables.

66. Illinois Oil-Field Brines: Their Geologic Occurrence and Chemical Composition: W. F. Meents, A. H. Bell, O. W. Rees, and W. G. Tilbury. 1952. 38 pp., 13 figs., 1 table.

Discusses the collection of brine samples, methods of brine analysis, and brine composition in relation to geologic occurrence. A detail table gives total solids and constituents in parts per million, in order of formation, county, and location.

67. Oil and Gas Development in Illinois During 1951: A. H. Bell and Virginia Kline. (Reprinted from Statistics of Oil and Gas Development and Production Covering 1951, Am. Inst. Min. Met. Eng.). 54 pp., 3 figs., 6 tables.

Circulars:

181. Mineral Resource Research and Activities of the State Geological Survey, 1951-52: M. M. Leighton. 1952. (Preprinted from the Ann. Rept. Dept. of Reg. and Ed. for Fiscal Year 1951-52). 58 pp., illus.

Describes the various activities of the State Geological Survey for the fiscal year July 1, 1951, to June 30, 1952.

182. Summary of Water Flood Operations in Illinois Oil Pools During 1951: P. A. Witherspoon and P. J. Shanor and Members of the Illinois Secondary Recovery and Pressure Maintenance Study Committee. 1953. (Joint publication with the Illinois Secondary Recovery and Pressure Maintenance Study Committee). 17 pp., 4 figs., 2 tables.

Summarizes the important work of the Committee in secondary recovery of oil in Illinois in 1951.

183. Short Papers on Geologic Subjects: H. A. Lowenstam and T. C. Buschbach. 1953. (Reprinted from Trans. Ill. Acad. Sci., vol. 45, 1952). 16 pp., illus.

Two papers on aspects of Illinois geology which were presented at the 1952 meeting of the Illinois Academy of Science.

184. Sands and Silts of Extreme Southern Illinois: A Preliminary Report: R. S. Shrode and J. E. Lamar. 1953. 28 pp., 1 fig., 5 tables.

Describes almost 40 deposits of sand and silt; gives 79 sieve tests, 16 chemical analyses, and data regarding mineral composition to serve as a basis for increasing the commercial production and utilization of these resources.

Miscellaneous:

Geologic Map of Illinois: Compiled by J. Marvin Weller et al. Reprinting.
Oil and Gas Drilling Report, mimeographed, issued monthly.
Supplementary Book of Charts for monthly Oil and Gas Drilling Report. 1952.

The Board Of Natural Resources And Conservation

BOARD OF NATURAL RESOURCES AND CONSERVATION

Honorable Vera M. Binks, Chairman

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George D. Stoddard, President, University of Illinois
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The Board of Natural Resources and Conservation, which directs and controls the work of the Geological Survey, the Natural History Survey, and the Water Survey, was created by the Civil Administrative Code in 1917. It is composed of distinguished scientists, each qualified by at least ten years professional experience in his special field, as shown above, and functions under the ex-officio chairmanship of the Director of the State Department of Registration and Education.

Under the law this Board selects and appoints, without reference to the State Civil Service law, all members of the technical staffs and approves the budgets and programs of the three scientific surveys. The Board is traditionally nonpartisan and its members serve without pay. Membership is by appointment of the Governor, and it is a standing tribute to the broad vision of our State administration and to the abilities of the Board members that since the Board's inception, changes on the Board have usually been made only upon the death or retirement of a member. Because several sciences, four different universities, and industry are represented by the Board membership, its points of view insure broad representation of the interests of the State.

The Board, which meets at regular intervals, receives and carefully studies quarterly reports from the three chiefs of the scientific surveys. It determines policies and acts in an advisory capacity over the manifold research and activities of the three surveys which are concerned with aiding in the development of and augmenting the natural resources of the State. The devotion of Board members to the responsibilities imposed upon them by law, their recognition of measures consistent with sound public policy, their comprehension of fruitful research programs, and their exercise of great care in selection of scientific staffs have resulted in national and international recognition of Illinois and its wealth of natural resources.

Recent outstanding capital improvements to the physical facilities of all three Surveys received the unqualified approval of the Board before they were submitted for the consideration of State authorities and the Legislature. Although the scientific surveys are administered by the State Department of Registration and Education, location of the

surveys' headquarters and principal laboratories on the University of Illinois campus at Urbana offers many advantages. Research is furthered through the availability of the University's libraries and some of the laboratories and experimental field-plots, and in like manner survey facilities are made available to University staff members and some advanced students seeking professional training. Cordial relations and a generous exchange of information between University and survey staffs make for prompt and effective dissemination of the results of research. Operational economy is also achieved by one system, maintained by the University, that provides water, heat, light, and other services for the surveys and the University.

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